

Analysis of Demand for the Structure of Earthquake-resistant and Energy-saving Buildings of the Rural Areas in Beijing

Pengxuan Duan^{*1}, Xiaoqun Zhou², Ying Li³, Qing Li⁴

¹National Key Laboratory of Solid Waste Resource Utilization and Energy-saving Building Materials, Beijing Building Materials Academy of Sciences Research

²Beijing Office of Wall Materials Innovation, Jin Ding north road No.69, Shijingshan District, Beijing, 100041, P.R China

^{*1}dpx2003@aliyun.com; ²zxq9999@sina.com; ³politegirl21@163.com; ⁴jessie_lq1983@126.com

Abstract

This paper investigates the basic building intuition of rural areas in Beijing, and analyzes the main problems of rural buildings. As for the building structures characteristics and building materials characteristics, this article put forward several building structure systems as the main technology demand of rural areas in Beijing, such as aerated concrete self supporting configuration structure system, heat preservation and decoration concrete bricklaying supporting configuration system.

Keyword

Rural Areas Building Structure; Earthquake-Resistant; Energy-Saving

Introduction

The rural residential building is the place where rural residents live their family life and engage in their household sideline production. The forms and contents of buildings in different regions are very different because of the different natural conditions, building materials, economic level, manners and costumes; on the other, the buildings have some common characteristics because of the consistency of basic requirements of the rural production life. Generally speaking, the rural residential buildings' functions should meet the demand of the family life and household sideline production. Besides the living rooms, production rooms and auxiliary facilities also should be included. There are many different requirements for the residential buildings' auxiliary facilities because of different specialized production and different nationalities inhabited areas. There are some differences in the topographic conditions, economic level, resident population, and functions. In northern China, the traditional rural residential buildings are mostly bungalows with symmetrical

arrangement. It formed as "Siheyuan" (quadrangle courtyard) or "Sanheyuan". The new house usually applied the layout types of dissymmetrical arrangement, the types of the principle room (the northern room) assistant with the eastern room (or western room), or only a series of one storey principle rooms. The bases of rural residences are usually rectangle.

There are 13 districts and 3985 villages in Beijing. There are 1183000 households with 3180000 people. The total area of constructions are about 191, 067, 555m² with per capita using space of 32.4m². The average construction area is 155.87m², and the average construction area of 100~200m² accounts for 51.4%, the 80~100m² average construction area accounts for 17.7% and 19.1% of less than 80m².

Basic Status of Rural Residential Buildings in Beijing

Construction Systems and Envelop Enclosure Structures

In Beijing, 98.9% of single-floor residential buildings and 1.1% of double or multi-storey buildings have not special construction drawing design. These buildings were built up by villagers themselves with traditional skills. They use common brick-concrete construction, with 370mm thickness load bearing wall and 240mm or 120mm thickness non-bearing wall. The surface of the wall is decorated by the coating, or decorated by the tile. Among that, 370mm thickness clay brick exterior wall accounts for 50.8% of the exterior wall, and 240mm clay brick exterior wall is about 33.7%. 90% of the exterior walls haven't applied the thermal insulation technology, therefore, the heat transfer coefficient is between 1.61 to 2.11 W/m²·K.

The doors and the windows are mostly located in the south. Among them, the wooden doors and windows account for 78.6%, the plastic steel one are 3.8%, the aluminium alloy and other materials doors and windows account for 17.6%. Only 27.9% of the doors and windows are two-layer wooden, plastic steel doors and windows which have some certain thermal insulation properties. Most of the doors and windows are made by villagers themselves. Recently, the new plastic steel doors and windows have been purchased from building materials market around. The heat transfer coefficient is between 2.68 to 6.4 W/m²·K.

The sloping roofs account for 94.1%, and flat roofs account for 5.9%. There is no thermal insulation technology applied on the roofs. Only less than 10% of the roofs were levelled by 200 thickness pan breeze.

The Heating Situation and the Indoor Comfortable Degree

In Beijing, more than 90% of the rural houses were heated by small domestic boilers. The coal is burned to provide heat power. Small quantities of the houses located in the mountains were heating assisted by the firewood. Only the used rooms were heated, and 66.1% of the heating rooms' average temperature was 10-15°C. And only 2.3% of the heating rooms' temperature reached up to 18°C. The average temperature of the rooms was lower than 12°C. However, the average coal consumption was about 40 Kg standard coals per square meter. In the rural area, each ton of the coal is about 500 RMB. The heating fee in winter occupied above 10% of the total aggregate income of the family. The heating fee in rural area is almost as much as the heating fee in the city where the power is from burning gas. The heating radiator is very hot; however, the room temperature is very low. Especially, the temperature is lower than 16°C in the evening.

The Main Problems of the Rural Residential Buildings in Beijing

Unsecure Structure

Beijing is in the convergence zone of Zhangjiakou-BO hai earthquake zone and Hei Bei plain earthquake zone. It is of some possibility to happen a great earthquake in Beijing. It is certainly defined in "Beijing seismic design specification" that the intensity of an earthquake resistance of buildings in Beijing is 8 degree. However, the rural buildings do not meet the seismic demand except the new buildings in the model

village. The safety performance of those structures is bad because of the unreasonable location and structure and the shallow and unstable foundation. The grave consequences "small earthquake and grave catastrophe" will happen.

Poor Thermal Insulation Property and High Energy Consumption

Compared to the limit value of heat transfer coefficient of the exterior protect constructions defined in the "Residential building energy efficiency design standards" (DBJ01-602-2004), most exterior protect constructions of the rural residential buildings have poor thermal insulation property recently.

TABLE 1 HEAT TRANSFER COEFFICIENT COMPARISON OF ENCLOSURE STRUCTURE

Types of buildings	Roofs	Exterior walls	windows	Door s	Air floor	Floors above the no heating space
4 storeys and the under constructions	0.45	0.45	2.8	1.7	0.5	0.55
Existing residential buildings	4.76	1.64	5.0-6.4			

The estimated heat consumption of the existing rural residential buildings is about 46W/m², which is far more than the city residential buildings whose target value of 14.65 W/m². The heating fee is excessively high; however, the room is very cold. People living there knew and applied very few about the renewable energy resources such as solar energy, marsh gas and straw, which also lead to the high construction consumption.

Bad Trend in the Building Energy Conservation Transformation of Rural areas

Recently, people chased blindly for the city model in the energy conservation transformation, which lead to the increase of the construction consumption of the whole society. The straw and wooden fire was replaced by the commercial energy such as coal, gas and so on, which caused the increase of the energy consumption. People use less traditional biomass fuel, which caused the increase of environmental pollution. In china, the output of the straw is about 600 million tons per year, and most of them have not been effectively applied by us. It will cause energy crisis if we blindly chased the city model in energy conservation transformation.

No Suitable Construction Systems for Rural Buildings

In Beijing, the main construction structure system included shear wall structure, masonry-concrete structure, frame shear wall structure, the pure frame structure, and steel structure, multi-story masonry structure, inside casting and outside masonry structure and so on. Among them, the shear wall structure, frame shear wall structure and steel structure were applied in high rise buildings. However, most of the rural buildings are low. The rural residential buildings mainly applied the masonry-concrete structure, and the masonry materials are mainly solid clay brick. There are lacks of new masonry construction systems for rural residential buildings after the solid clay brick forbidden.

Unsound Building Materials Supply and Service System

There are few new building materials and energy saving and thermal insulation materials in the building materials market around the rural areas. Rural people do not familiar with application technology of the new residential buildings systems. They have weak awareness of saving energy, and they lack of knowledge about construction security. The chain of new systems' propagandizing and popularizing, design, manufacture, delivery, construction and after-sales service is imperfect.

Bad Constructional Structure Safety and Short Lifespan of Some Rural Constructions

Due to the lack of some necessary construction structure standards, a lot of types of construction structures come out in constructions of the new rural. Some of the demonstration buildings only concentrate on the thermal insulation properties, instead of ignoring the buildings' safety and life span. Some of the demonstration buildings use the light steel keel with mortar layer of polystyrene as the exterior wall. Some of the buildings apply the light steel keel big circuit board and gypsum plasterboard as the exterior wall and some of them use the magnesite products as the exterior wall. All of them have poor impacts on the resistance and durability of buildings. In the countryside, the streets are narrow, and there are a lot of farm machines and big animals. If these machines and animals strike the exterior walls, the walls will be broken, and even the whole building will collapse. If the exterior walls were built by magnesite products, the exterior wall coating will be peeled and shed from

the exterior wall. These problems have come out in the sample county; therefore, we should pay more attention to the life span of the rural residential buildings.

Comparison and Selection of Main Technologies of the Seismic Energy Saving Residential Construction Structure System

Autoclaved Aerated Concrete Reinforcement Bearing Masonry Structure System

The autoclaved aerated concrete reinforcement bearing masonry structures system is the system that properly used the autoclaved aerated concrete as the bearing and thermal insulation materials to form single layer or multi-layer buildings. The buildings only with single material can meet the requirements of energy saving and proper structure. The mechanical principle of seismic of the structure system is similar to the ordinary brick structure system. The autoclaved aerated concrete block is the only thermal self-insulation wall material that could meet the 65% energy saving requirement. If use the 300 mm thickness autoclaved aerated concrete block (05 level) as the exterior walls, the heat transfer coefficient of exterior is 0.56 W/(m²·K), which meet the requirement of 65% energy saving in Beijing. If this system could be used in countryside wildly, it both meets the requirement of rural people's secure use and construction buildings energy saving.

It can be applied on various types of rural residential buildings such as multi-storey apartments, double-storey villa and single storey quadrangle dwellings.

The price of the autoclaved aerated concrete block is about 200-230 RMB/cube meter. If built a 170 square meters (Gross leasable area) double-storey residence with the block, the comprehensive price will be 1100 RMB/square meter. If built the 150 square meters quadrangle dwelling, the comprehensive price will be 1150.6 RMB/square meter. If the area of quadrangle dwelling is 260 square meters, the install project cost is about 1000RMB.

As a new structure system, there is no formal technology specification for the autoclaved aerated concrete block system as the design reference. The promotion of the autoclaved aerated concrete reinforcement bearing masonry structures system is not very smoothly.

The important technology point of rural residential constructions is to research and develop the autoclaved aerated concrete reinforcement bearing masonry structure system and its supporting material system. Do some important researches on Structure and mechanical properties, thermal performances, seismic performances, workability of the supporting mortar, hardening body performances and mechanical properties of the masonry. According to the researches, the application technology specifications, design specifications, standardschematic handbook, and construction regulations will be written.

Thermal Insulation Decorated Concrete Block Bearing Structure System

The thermal insulation decorated concrete hollow blocks are applied in this system (with EPS), and the thickness of the block is 310mm, the reinforcement of the core column and ring beam should meet the seismic requirement. Precast concrete plank and EPS board are used as the roof; hollow double glass and plastic steel window is used into outside window. Solar power is applied into heating system and hot water supply system. With high strength, good ductility and seismic resistance, good workability and low cost, the reinforced masonry is the perfect system which could match with the reinforced concrete structure. It is very popular in the developed countries. Its characteristics are thermal insulation, load bearing, decoration, fast construction speed and light weight.

This system is suitable for population and application in rural residential constructions.

It can be applied on various types of rural residential buildings such as multi-storey apartment, double-storey villa and single storey quadrangle dwellings.

Estimated according to the double storey residence with gross leasable area of 170m², the comprehensive cost is 1114.2RMB/m².

There are no universally accepted standards, therefore, the quality of the thermal decorated concrete block is also hard to confirm. Nowadays, there are few factories and products; therefore, the price of the product is expensive.

Concrete Frame Structure Filling Masonry System

Concrete frame structure filling masonry system uses the steel concrete frame as the construction load bearing structure, and then uses the light materials (such as autoclaved aerated concrete blocks, gypsum

blocks, clay blocks, and construction light boards to fill) as the protect walls and internal parting walls. The technology is mature and reliable, which could be used in the medium and large industry and domestic constructions. We executed the "Concrete Structure Design Regulation" GB 50010-2002, "Seismic Resistance in Construction Design" GB 50011-2001. The theoretical system is mature and the work technology is reliable. And the materials could be mostly used into the multi-storey and high-rise buildings with the seismic fortification intensity of 6-9 degree. It is a reliable and safety system according to the long-term engineering practice.

This system is popularly used in the industry and public facilities, and is less used in the common residential buildings.

Its construction requirements are higher, and it is less used into the city common residential buildings because of the limitation of the structure system. It is also not suitable for the rural residential buildings.

Insulation Bricks Cast-in-situ Main Wall System

This system applied non-vertical holes and horizontal grooves EPS crystal concrete thermal insulation mold casting. The level holes and vertical holes crossed with each other and then the grid shapes were formed after holes staggered joint masonry. The self compacting concrete is filled into the holes to form the bearing shear wall. Along the top of interior and exterior walls, the closed ring beam was installed, and the floor slabs was cast-in-place. The reinforcement column was settled in the joint place of interior and exterior wall or under the bearing beam, which formed an integrated cast-in-situ bearing system.

This system has the characteristics of good structure, thermal insulation, and sound insulation. It belongs to the shear wall bearing system. It is suitable for the high-rise flats.

The insulation bricks mould system belongs to shear wall bearing system, and it is suitable for high-rise flats. If use it into one to three storey low-rise rural residential buildings, its economic advantages could not exist anymore because of the high cost of the shear wall.

If use the thermal insulation cast-in-situ bearing wall system into common rural residential buildings, they can meet the requirement of 65% energy saving with the construction style of two layers terrace housing with steel concrete roof, and the coating using on the

exterior walls. The cost of every square meters is about 1350RMB, estimated according to 170m²/households.

Thus it can be seen, though the thermal insulation cast-in-situ bearing wall system has a lot of excellent performances, it is not suitable for the low level of rural residential buildings, and its advantages are hard to play; therefore, it is not suitable for promotion in the rural areas.

Results and Suggestions

Results

(1) Rural residential buildings' structure safety and thermal insulation property should be improved in Beijing.

(2) Rural residential buildings' construction systems which really meet the requirements of the countryside should be quickly pushed out in order to improve the seismic energy saving property and the life span.

(3) The Environmental protection wall materials and the supporting material systems which really meet the earthquake resistant and energy-saving requirements of the rural residential buildings should be quickly pushed out in order to improve the environmental conservation and supporting property of the rural residential building materials.

(4) The new power should be quickly pushed forward in rural construction in order to improve the energy efficiency.

(5) The technology regulations should be quickly developed in order to govern, guide and regular the Beijing new rural residential buildings construction.

Suggestions

(1) Improve the researches on autoclaved aerated concrete reinforcement bearing masonry structure system.

(2) Complete the researches of the reinforcement

autoclaved aerated concrete masonry system, FGD construction gypsum masonry system and some matched materials system.

(3) Based on the regulations of "Rural Residential Building Aseismic Design and Construction Procedures in Beijing", finish the specifications of "Code for Design of Rural Housing", "Rural Residential Construction, Construction Transformation Approval Technology Regulation", and "Standard Schematic Handbook of Rural Residential Buildings".

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